CHAPTER 10. WATER QUALITY

CONTENTS

TABLES

FIGURES

1.0 INTRODUCTION

The potential adverse effects of urban runoff on the physical, chemical, and biological characteristics of receiving waters have been widely documented (e.g., WEF/ASCE 1992, 1998; Debo and Reese 2002; Horner, et al. 1994; Schueler and Holland 2000). Traditional storm water management focused on moving water away from people, structures, and transportation systems as quickly and efficiently as feasible. This was accomplished by creating conveyance networks of impervious storm sewers, roof drains, and lined channels, which concentrated runoff discharges to receiving waters. There were many water quality consequences of this traditional approach to drainage including:

- Introduction of new pollutant sources and types.
- Increased runoff temperature.
- Habitat damage and ecosystem disruption associated with streambed and bank erosion leading to sediment and pollutant transport.
- Channel widening and instability.
- Destruction of both aquatic and terrestrial physical habitats.
- Increased contaminant transport, leading to increased water quality degradation that often may result in regulatory consequences such as stream segments being listed as impaired on the State 303(d) list and requirements for Total Maximum Daily Load (TMDL) allocations for dischargers to the stream.
- Production of potentially toxic concentrations of contaminants in receiving waters and long-term accumulation of contaminants.

To minimize potential adverse impacts of urbanization and improve water quality, the City of Springfield, Missouri (Springfield), along with many communities around the United States, encourages the widespread use of storm water Best Management Practices (BMPs) on all development sites. The purpose of this chapter is to provide guidance for selecting, designing, and maintaining BMPs. One of the fundamental principles of a sound storm water management program is the requirement that new developments should be designed to reduce runoff velocities, runoff volumes, and pollutant loads. This can be achieved with properly designed, implemented and maintained storm water BMPs. This section is primarily targeted at protecting water quality in conjunction with development and redevelopment of residential and commercial areas; however, BMPs for light industrial areas and other types of land uses are also addressed. The design guidelines in this chapter represent current BMP technology and are anticipated to evolve as BMP technology is evaluated and refined, new BMPs are developed, or as new standards are promulgated by the State. This chapter significantly draws from the Denver Urban Drainage and Flood Control District's (UDFCD's) *Urban Storm Drainage Criteria Manual, Volume 3, Best Management Practices*, first published in 1992 and regularly updated since them. Volume 3 updates and other information are available from the UDFCD website (www.udfcd.org).

This chapter presents design requirements for both structural and non-structural water quality BMPs. General BMP descriptions, design considerations and criteria, maintenance considerations, design forms and completed examples are provided for each structural BMP. The discussion in this section is limited to permanent, post-development BMPs. For information on construction-phase erosion and sediment control BMPs, the *City of Springfield Erosion and Sediment Control Guidelines* (City of Springfield 2000) should be referenced.

2.0 APPLICABILITY

The water quality requirements outlined in this chapter are applicable under the following development conditions:

- New residential development greater than 2 acres.
- New commercial/industrial/multi-family development greater than 1 acre.
- Other new developments and significant redevelopments where significant water resources are at risk of being impacted.

3.0 WATER QUALITY REQUIREMENTS

The primary objectives of Springfield's water quality requirements are to:

- Protect drinking water supplies.
- Protect public health and safety related to water resources.
- Maximize the quality of water resources to enhance the quality of life
- Enable recreational opportunities where feasible and beneficial.
- Meet federal National Pollutant Discharge Elimination System (NPDES) program requirements.

3.1 Water Quality Design Principles

Water quality design principles for new developments shall adopt the following:

1. **Minimize the amount of runoff.** The total quantity of pollutants transported to receiving waters can be minimized most effectively by minimizing the amount of runoff. Both the quantity of runoff and the amount of pollutant wash-off can be reduced by minimizing directly connected impervious area (DCIA). Impervious areas are considered connected when runoff travels directly from roofs, driveways, pavement, and other impervious areas to street gutters, closed storm drains, or concrete or other impervious lined channels. Impervious areas are considered disconnected when runoff travels as sheet flow over grass areas or through properly designed BMPs, prior to discharge from the site.

2. **Maximize contact with grass and vegetated soil.** The opportunity for pollutants to settle can be maximized by providing maximum contact with grass and vegetated soil. Directing runoff over vegetative filter strips and grass swales enhances settling of pollutants as the velocity of flow is reduced.

3. **Maximize holding and settling time.** The most effective runoff quality controls reduce both the runoff peak and volume. By reducing the rate of outflow and increasing the time of detention storage, settling of pollutants and infiltration of runoff are maximized.

4. **Design for small, frequent storms.** Drainage storm water systems for flood control are typically designed for large, infrequent storm events. In contrast, quality controls are designed for small, frequent storm events. In Springfield, 90 percent of all rainfall events are 1 inch or less. Studies indicate that most pollutants are washed off in the "first flush," generally considered the first ½ inch of runoff.

5. **Utilize BMPs in series where feasible.** Performance monitoring of BMPs throughout the country has shown that the combined effect of several BMPs in series can be more effective in reducing the level of pollutants than just providing a single BMP at the point of discharge. To the extent practical, impervious areas should be disconnected and runoff should be directed first to vegetative filter strips, then to grass swales or channels, and then to extended detention basins, sand filters, etc.

6. **Incorporate both flood control and storm water quality objectives in designs, where practical.** Incorporating both flood control and water quality enhancement into a single storm water management facility is encouraged whenever practical. Combining several objectives, such as water quality enhancement and flood control, maximizes the cost-effectiveness of storm water management facilities.

7. **Provide special care for runoff from fueling areas and other areas having a high concentration of pollutants.** Runoff from these areas must be directed to a properly designed BMP that provides both filtration and settling prior to discharge to receiving waters.

3.2 Storm Water NPDES Permit

Under the *Missouri Clean Water Law* and the *Federal Clean Water Act*, the Missouri Clean Water Commission of the Department of Natural Resources issued Missouri State Operating Permit MO-0126322 to the City of Springfield, thereby authorizing discharges from Springfield's Municipal Separate Storm Sewer System (MS4) to waters of the State. This permit is provided in Appendix C. For more information on the history and requirements of the storm water NPDES permit program, see the U.S. Environmental Protection Agency (USEPA) website http://cfpub2.epa.gov/npdes/stormwater/phase1.cfm.

Under Springfield's permit, the City is required to develop and implement a comprehensive Storm Water Management Program including controls necessary to identify illicit discharges, effectively reduce the discharges of non-storm water into the MS4 and reduce the discharge of pollutants from the MS4 to the Maximum Extent Practicable (MEP). An overview of the specific storm water quality management requirements of the City's permit, as reissued January 4, 2002, includes the following:

1. Operation and maintenance of structural controls (i.e., BMPs) in a manner to reduce the discharge of pollutants to the MEP.

2. Control of discharges from areas of new development and significant redevelopment (based on BMPs).

3. Operation and maintenance of public streets, roads and highways in a manner to minimize discharge of pollutants, including those related to sanding and deicing activities.

4. Assessing flood management project impacts on receiving water quality and evaluating the feasibility of retrofitting existing structural control devices to provide additional pollutant removal from storm water.

5. Implementing a program to monitor pollutants in runoff from municipal waste management facilities that aren't covered under a separate permit.

6. Implementing controls to reduce the discharge of pollutants associated with pesticides, herbicides and fertilizers.

7. Prohibiting illicit discharges and improper waste disposal to the MS4 (i.e., effectively prohibiting non-storm water discharges to the MS4). Extensive field screening is an important aspect of this task.

8. Monitoring and controlling pollutant discharges from industrial and other high-risk sites.

9. Developing and implementing a program to reduce pollutant discharges to the MEP from construction sites involving more than one acre of land.

The permit emphasizes control of illicit discharges to the MS4; therefore, it is important to note that the permit specifically allows the following non-storm water discharges to the system:

- Water line flushing
- Uncontaminated groundwater infiltration
- Foundation and footing drains
- Springs
- Non-commercial car washing
- Street wash waters
- Landscape irrigation/lawn watering
- Discharges from potable water sources
- Air conditioning condensate
- Water from crawl space pumps
- Natural flows from riparian habitats and wetlands
- Fire fighting activities

The City is required to submit an annual report the State documenting the activities completed under its Storm Water Management Program. Failure to comply with the requirements of the permit has serious administrative, civil and/or criminal penalties.

4.0 BMP PLANNING PROCESS

Urban storm water runoff can contain a variety of pollutants that can adversely impact waterbodies. The Nationwide Urban Runoff Program (USEPA 1983) and other studies widely document the types and concentrations of pollutants associated with various land use types. To reduce the concentrations and the loads of these constituents reaching receiving waters, a variety of both structural and non-structural storm water BMPs should be implemented. Structural BMPs are constructed facilities designed to passively treat urban storm water runoff, including practices such as detention basins (both dry basins and wet ponds), wetlands, porous pavement, and the use of vegetated zones, among others. Structural BMPs can be designed to treat small volumes of storm water on development sites or to serve larger regional drainage areas. Non-structural BMPs are practices and procedures to minimize or prevent pollution and control it at its source through activities such as public education, proper materials handling and storage, and minimizing directly connected impervious areas.

To guide selection and design of structural BMPs, the following four-step process should be followed,:

1. Employ runoff reduction practices.

2. Provide treatment for the specified water quality capture volume.

3. Stabilize downstream drainageways.

4. Consider the need for industrial and commercial BMPs.

This chapter focuses on Steps 1, 2 and 4, while Chapter 8, Open Channels describes methods of stabilizing drainageways. Additional information on Steps 1 and 2 follow in this section, and information on Step 4 follows in Sections 5.8 and 5.9.

4.1 Runoff Reduction and Minimizing Directly Connected Impervious Area

DCIA is impermeable area that drains directly to the improved storm drainage system. Minimizing DCIA is a land development design philosophy that seeks to reduce paved areas and direct storm water runoff to landscaped areas, grass buffer strips, and grass-lined swales to slow down the rate of runoff, reduce runoff volumes, attenuate peak flows, and encourage filtering and infiltration of storm water. This approach increases the time of concentration, in contrast to historic approaches that result in a fast responding system, as well as increased runoff volumes and relatively large peak runoff rates during small storms. Minimizing DCIA can also reduce pollutant loads to the storm water treatment system because of increased infiltration of runoff near the point where it begins.

Minimizing DCIA can be integrated into the landscape and drainage planning for any development. Drainage from rooftop collection systems, sidewalks, and driveways can be directed to landscaped areas, infiltration areas such as porous landscape detention and porous pavement, grassed buffer strips, or to grass swales. Instead of using solid curbing, curbing can be eliminated in some areas or slotted curbing can be used along with stabilized grass shoulders and swales. Residential driveways can use porous pavement or their runoff can be redirected to the lawn rather than the street. Large parking lots can minimize DCIA by using porous pavement to encourage local infiltration or storage. Green roofs may also be used as a tool to minimize DCIA.

Site slopes should be designed to direct storm water runoff as sheet flow away from buildings, roads, and parking lots toward grass-covered or other pervious areas prior to reaching the storm water conveyance systems or other BMPs. In areas of high permeability soils (Hydrologic Soil Groups A and B), surface runoff may be successfully infiltrated, whereas areas of less permeable soils may require underdrain systems to reduce surface runoff. Steep sites with average terrain slopes exceeding 5 percent may not be well suited to implementing some aspects of these BMPs. Steep sites can be addressed by using terracing or retaining walls.

Minimizing DCIA can be implemented in varying degrees. UDFCD (1999) characterizes two general levels associated with minimizing DCIA as follows:

- Level 1. Typically, the first step is to address minimizing DCIA at a site development level. This approach typically involves directing runoff from impervious surfaces to flow over grass-covered areas and providing sufficient travel time to encourage the removal of suspended solids before runoff leaves the site, enters a curb and gutter, or enters another storm water collection system. Thus, at Level 1, *all* impervious surfaces are designed to drain over grass buffer strips before reaching a storm water conveyance system.

- Level 2. A more advanced approach is to also minimize DCIA at the subdivision level. In addition to the measures taken in Level 1, this level replaces solid street curb and gutter systems with no curb or slotted curbing and low-velocity grass-lined swales and pervious street shoulders. Conveyance systems and storm sewer inlets will still be needed to collect runoff at downstream intersections and crossings where storm water flow rates exceed the capacity of the swales. Small culverts will be needed at street crossings and at individual driveways until inlets are provided to convey the flow to a storm sewer.

Implementing Level 1 is typically encouraged and can reduce or eliminate the need for other structural BMPs such as extended detention basins. Implementing Level 2 involves a public street design differing from public improvement standards and will therefore require early planning with Springfield staff and subdivision variances in accordance with subdivision regulations.

Refer to Figure WQ-1 to determine the effective impervious percentages associated with Level 1 and Level 2 efforts to minimize DCIA. For more information, refer to Section 6.0, Low Impact Development.

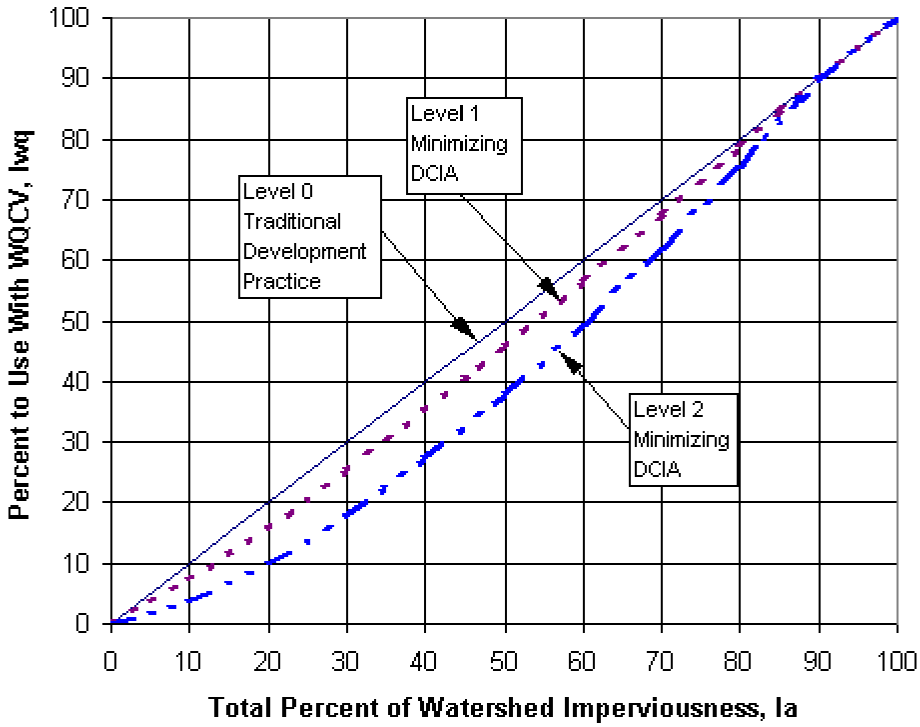

Figure WQ-1
Imperviousness Adjustments for Level 1 and 2 of Minimizing DCIA
(Source: *Urban Storm Drainage Criteria Manual, Volume 3, Best Management Practices*, UDFCD, 1999)

4.2 Determining the Water Quality Capture Volume

Studies indicate that small-sized, frequently occurring storm events account for the majority of events that result in storm water runoff from urban catchments. Consequently, these frequent storms also account for a significant portion of the annual pollutant loads. Capture and treatment of storm water from these small and frequently occurring storms is the recommended design approach for water quality enhancement, as opposed to flood control facility designs that focus on less frequent, larger events. Incorporation of both sets of criteria into a single storm water management facility is encouraged, where practical.

The required water quality capture volume (WQCV) in cubic feet (ft^3) to be used in design of water quality BMPs shall be the greater of the following:

1. The first ½ inch of runoff from the directly connected impervious area in the development, or

2. The runoff resulting from a rainfall depth of 1 inch over the entire development, calculated using the SCS Curve Number Method (See Chapter 5, Calculation of Runoff).

Use of BMPs that minimize DCIA to filter and infiltrate site runoff can reduce treatment requirements for the WQCV. For example, sites including a grass buffer design in accordance with the criteria in Section 5.1 of this chapter may not require additional treatment of the WQCV.

4.3 Other Important Considerations for BMP Selection

4.3.1 General

In addition to the design considerations above, the following factors should be considered when selecting BMPs for a site:

- Pollutants Controlled: The BMPs should effectively control pollutants known to be associated with the tributary land use.

- Reliability/Sustainability: Measures should be effective over an extended time and be able to be properly maintained over time.

- Public Acceptability: BMP selection should consider the expected response from the public, particularly neighboring residential properties, if any.

- Agency Acceptability: BMP selection should consider the expected response of agencies that will oversee the BMPs and their relationship to regulatory requirements.

- Risk and Liability: Control measures should be evaluated in terms of the risks or liabilities that occur during implementation. Public safety is always one of the most important design considerations, not only for "traditional" drainage structures, but also for BMPs.

Once the BMPs are implemented, it is necessary to ensure that structural BMPs are properly operated and maintained and that the relevant non-structural BMPs are also being implemented. This may involve requiring subdivision covenants, inspecting BMPs, designating individuals responsible for BMPs, and pollution prevention education. Modifications to BMPs over time may also be necessary if land uses or other factors change or if BMPs prove to be ineffective or a nuisance.

4.3.2 Mosquitoes and Storm Water BMPs

The potential for mosquito breeding and the spread of mosquito-borne illnesses in storm water BMPs must be addressed. Mosquito breeding in storm water management facilities is a potential problem that can be effectively controlled or at least mitigated through proper design, construction, and maintenance. In general, the biggest concern is the creation of areas of shallow stagnant water with low dissolved oxygen that creates a prime mosquito habitat. Other habitat characteristics that may enhance breeding include dense stands of vegetation that may protect larvae from natural predators and soils with high organic content. While storm water BMPs such as detention ponds and constructed wetlands often includes these features, careful design and proper management and maintenance of systems can effectively control mosquito breeding.

The key to minimizing breeding is to avoid creating areas of shallow standing water. Studies indicate that pools of deep water (≥ 5 feet) and pools with residence times less than 72 hours are less likely to breed mosquitoes. Permanent pools are generally less of a concern than dry detention due to greater depth; therefore, dry detention designs require outlets to drain in 24 to 48 hours. Constructed wetland design guidelines recommend varying bottom elevations; however, caution should be applied to avoid isolated pools during dry weather (for storm water supported systems) that may sustain larvae. Constructed wetland designs that incorporate low-flow channels keep water moving through and/or around the system, thereby increasing oxygen levels to discourage mosquito production. Constructed wetlands with baseflow or on-line systems may prevent suitable mosquito habitats from forming. Vegetation density should be controlled to maintain mixing and to allow predator access. A fluctuating water surface, such as from a fountain in a wet pond, also discourages mosquitoes.

Proper BMP maintenance is also essential for controlling mosquito populations. For example, it is important to periodically remove sediment from inflow pipes and culverts to reduce small pools of standing water. Dead or decaying vegetation, including grass clippings from right-of-way or embankment mowing, should be removed regularly.

5.0 STRUCTURAL BEST MANAGEMENT PRACTICES

Structural BMPs described in this section include vegetated filter strips/grass buffers, grass swales, extended dry detention basins, extended wet detention basins, constructed wetland basins, modular block porous pavement, porous landscape detention, and proprietary packaged storm water treatment systems. A brief description of each BMP is provided followed by design procedures and criteria and maintenance considerations. Experience with many of the BMPs in Springfield is limited as of the spring 2007 (when this manual was initially published). Thus, as experience with BMP design, construction, monitoring, and maintenance builds, the criteria listed below may require adjustment.

5.1 Vegetative Filter Strip/Grass Buffer

5.1.1 Description

Vegetated filter strips/grass buffer strips are uniformly graded and densely vegetated areas of turfgrass, planted native grasses, or adequate existing grass. They require sheet flow to promote filtration, infiltration and settling of runoff pollutants. Grass buffers differ from grass swales in that they are designed to accommodate overland sheet flow rather than concentrated or channelized flow. Grass and other vegetation provide aesthetically pleasing green space, which can be incorporated into a landscaping and bufferyard plan. In addition, their use typically adds little cost to a development when incorporated into the existing green space requirements, and their maintenance should be no different than routine maintenance of onsite landscaping.

Grass buffers can be utilized for a variety of land uses and are typically located adjacent to impervious areas. Because of the amount of space required for grass buffers to meet full water quality requirements, additional BMPs are often required. Grass buffers can be used on many sites and are strongly encouraged to provide first flush pollutant removal and infiltration for small rainfall events.

Because the effectiveness of grass buffers depends on having an evenly distributed sheet flow over their surface, the size of the contributing area and the associated volume of runoff must be limited. Whenever concentrated runoff occurs, it should be evenly distributed across the width of the buffer via a flow spreader. This may be a porous pavement strip or another type of structure used to achieve uniform sheet-flow conditions.

5.1.2 Design Considerations

Design of a grass buffer is based primarily on maintaining sheet-flow conditions across a uniformly graded area with a gentle slope and a dense grass cover. When a grass buffer is used over unstable slopes, soils or vegetation, formation of rills and gullies that disrupt sheet flow will occur. The resultant short-circuiting will invalidate the intended water quality benefits and must be corrected through maintenance. A rectangular strip is the preferred shape for a grass buffer and should be free of gullies or rills that concentrate the flow over it.

Grass buffers should be protected from excessive pedestrian or vehicular traffic that can damage the grass cover and affect uniform sheet-flow distribution. Topsoil that is free of rocks and debris must be spread over the grass buffer area to promote a healthy stand of grass. A mixture of grass and trees may offer benefits for slope stability and improved aesthetics.

5.1.3 Design Procedure and Criteria

The following steps outline the grass buffer design procedure and criteria. Figure WQ-2 is a schematic of a grass buffer facility and its components.

1. Calculate the 2-year peak flow rate, $Q_{2\text{-}year}$ (cfs), of the area draining to the grass buffer as described in Chapter 5, Calculation of Runoff.

2. The minimum design length, L_G (ft), (normal to flow) is calculated as:

$$L_G = \frac{Q_{2-year}}{0.05} \qquad \text{(Equation WQ-1)}$$

3. The minimum width, W_G (ft), along the sheet flow direction, is the greater of the following calculations:

$$W_G = 0.2 L_I \qquad \text{(Equation WQ-2)}$$

or 6 feet (for sheet flow control)

$$W_G = 0.15 \left(A_t / L_t \right) \qquad \text{(Equation WQ-3)}$$

or 6 feet (for concentrated flow control)

In which:

L_I = Flow path length of sheet flow over the upstream impervious surface (ft)

A_t = Tributary area (ft^2)

L_t = Length of the tributary inflow normal to flow spreader (i.e., width of flow spreader) (ft)

4. The slope in the direction of flow, S, shall not exceed 4 percent.

5. Incorporate a device on the upstream end of the buffer to evenly distribute flows along the design length.

6. Sod or seed the grass buffer and cover with suitable erosion control until vegetation is established. Seeding and mulching alone is not an acceptable method of erosion control.

7. Provide a means for outflow collection. The buffer can drain to a grass swale, storm sewer, or street gutter in accordance with design criteria for those facilities. In some cases, the use of

underdrains can maintain better infiltration rates as the soils saturate and help dry out the buffer after storms or irrigation periods.

5.1.4 Maintenance

If the grass buffer is located adjacent to urban activity, routine mowing of the strip may be necessary to maintain aesthetic value. Eventually, the grass strip next to the spreader or the pavement will have accumulated sufficient sediment to block runoff. At that time, a portion of the grass buffer strip will need to be removed and replaced. Additional maintenance criteria are included in Chapter 12, Easements and Maintenance.

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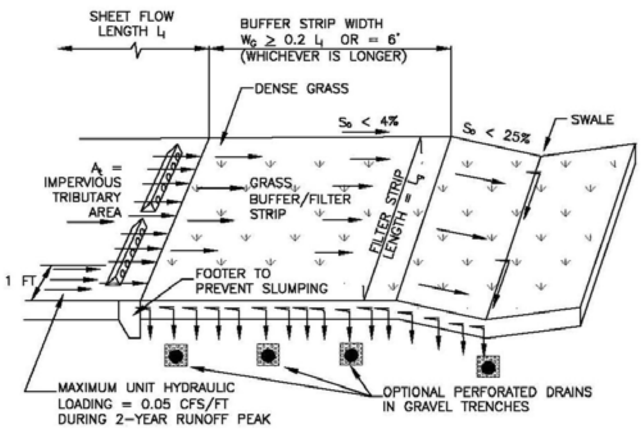
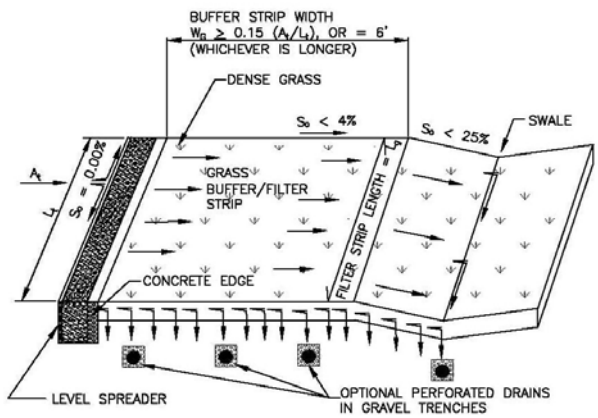


SHEET FLOW CONTROL
NTS



CONCENTRATED FLOW CONTROL
NTS

GRASS BUFFER

Figure WQ-2
Application of Grass Buffers (Filter Strips)

5.1.5 Design Example

The following example demonstrates use of the Grass Buffer (GB) Worksheet in the SF-BMP Spreadsheet to determine the length and width of a grass buffer, given the contributing drainage area and 2-year peak flow rate. DETAILS TO BE DETERMINED

Data Input (for GB)

Results (for GB)

Insert Image of Completed Spreadsheet For (GB) Here

5.2 Grass Swale

5.2.1 Description

A grass swale sedimentation facility is a densely vegetated drainageway with gentle side slopes that collects and slowly conveys runoff. A grass swale can be located to collect overland flows from areas such as parking lots, buildings, residential yards, roadways and vegetative filter strips/grass buffers. A grass swale is set below adjacent ground level, and runoff enters the swale over grassy banks. Swales in residential and commercial settings can also minimize DCIA by using them as an alternative to a curb-and-gutter system. A grass swale is generally less expensive to construct than a concrete or rock-lined drainage system, and a grass swale can also provide some reduction in runoff volumes from small storms through infiltration. The grass swale should be vegetated with dense grasses that can reduce flow velocities and protect against erosion during larger storm events.

5.2.2 Design Considerations

A grass swale is sized to maintain a low velocity during small storms and to collect and convey larger runoff events. A grass swale generally should not be used where site slopes exceed 5 percent. The longitudinal slope of a grass swale should be kept to less than 1 percent, which often necessitates the use of grade control checks or drop structures. Figure WQ-3 shows trapezoidal and triangular swale configurations. If one or both sides of the grass swale are also to be used as a grass buffer, the design of the grass buffer must follow the requirements of Section 5.1.

5.2.3 Design Procedure and Criteria

The following steps outline the grass swale design procedure and criteria. Figure WQ-3 is a schematic of a grass swale facility and its components.

1. Calculate the 2-year peak flow rate, $Q_{2\text{-}year}$ (cfs), to be conveyed in the grass swale as described in Chapter 5, Calculation of Runoff. For public improvements, the grass swale must meet the criteria given in Chapter 8, Open Channels. For all developments with detention, it must be shown that the channel can convey the maximum design flow to the detention basin and that bypass will not occur.

2. The geometry of the cross-section should be either trapezoidal or triangular with side slopes of 4H:1V or, preferably, flatter.

3. The longitudinal slope, S_o, of the grass swale should be kept to less than 1 percent. If the longitudinal slope requirements cannot be satisfied with available terrain, grade-control checks or small drop structures must be incorporated to maintain the required longitudinal slope. (See Chapter 8, Open Channels.)

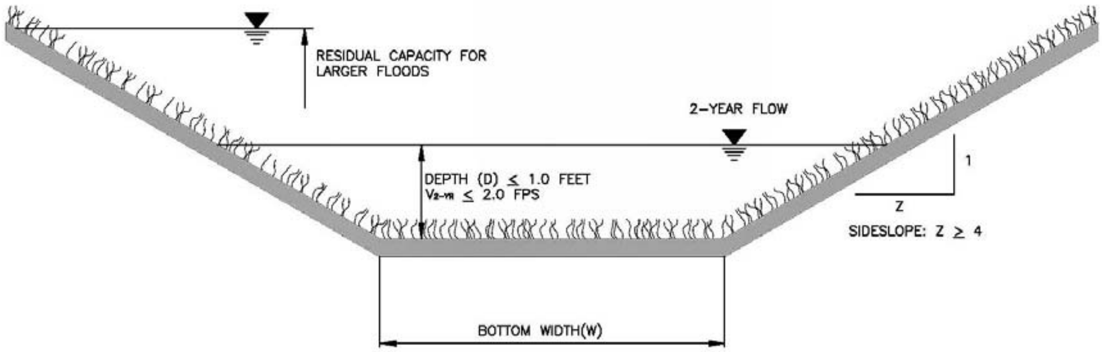
4. To promote sedimentation and water quality treatment, the maximum velocity of the 2-year peak flow shall not exceed 2 feet per second (ft/s) and the maximum flow depth of the same flow shall not exceed 1 foot.

5. Sod or seed the grass swale and cover with suitable erosion control until vegetation is established. Seeding and mulching alone is not considered an acceptable method of erosion control.

6. If applicable, small culverts at each street crossing and/or driveway crossing may be used to provide onsite storm water capture volume in a similar fashion to an extended dry detention basin (if adequate volume is available).

5.2.4 Maintenance

Dense turfgrass must be maintained within a grass swale to retain optimal performance as a water quality BMP. The grass swale must be mowed in accordance with Springfield mowing ordinances unless a maintenance plan for other maintenance methods has been approved by Public Works. If check dams are installed in the grass swale, sediment may accumulate up-gradient of check dams. Accumulated sediment should be removed when sediment depth exceeds 6 inches, or as necessary to prevent the deposition of sediment downstream. Additional maintenance criteria are included in Chapter 12, Easements and Maintenance.



TRAPEZOIDAL GRASS-LINED SWALE SECTION
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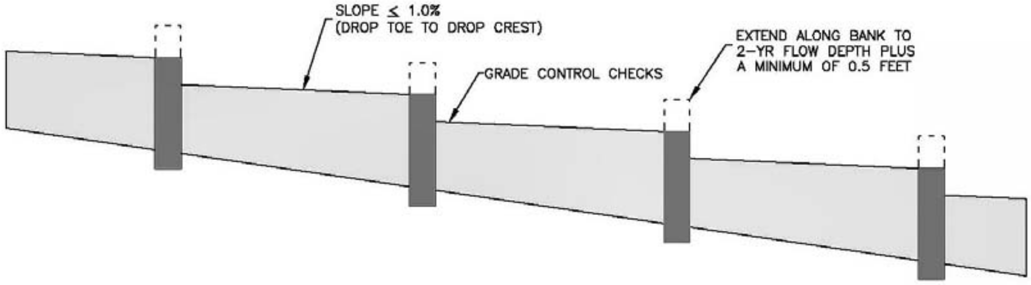

GRASS-LINED SWALE PROFILE
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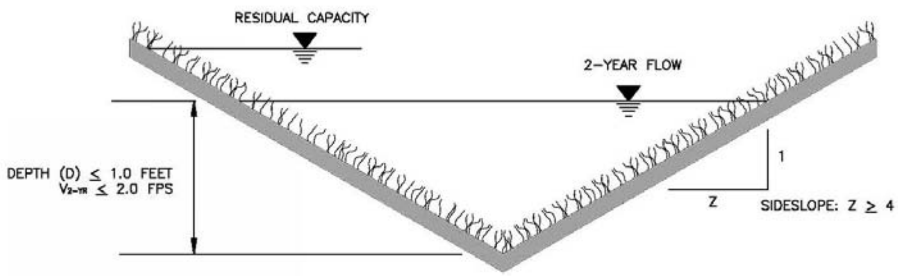


TRIANGULAR GRASS-LINED SWALE SECTION
NTS

Figure WQ-3
Profile and Sections of a Grass Swale

5.2.5 Design Example

The following example demonstrates use of the Grass Swale (GS) Worksheet in the SF-BMP Spreadsheet to determine xxx. DETAILS TO BE DETERMINED

Data Input (for GS)

Results (for GS)

INSERT IMAGE OF COMPLETED SPREADSHEET FOR (GS) HERE

5.3 Extended Dry Detention Basins

5.3.1 Description

An extended dry detention basin is designed to collect the runoff from smaller, more frequent rainfall events and release the runoff over a longer period of time. An extended dry detention basin collects and treats the “first flush” runoff which typically has a higher concentration of most pollutants found in urban runoff. The basins are considered to be "dry" because they are designed not to have a significant permanent pool of water remaining between storm runoff events. An extended dry detention basin can be used for regional or on-site treatment or as follow-up treatment in series with other BMPs.

An extended dry detention basin should typically be designed and maintained to pool water for no more than the design drawdown time of 24 to 48 hours. In cases where there is a sufficient distance between the extended dry detention basin and the nearest residential land use, it may be desirable to allow pools to form and wetland vegetation to grow. These plants generally provide water quality benefits through pollutant uptake, but they often cause public complaints when located near a residential area. In addition, the bottom will be the depository of all the sediment that settles out in the basin. As a result, the bottom can be muddy and may have an undesirable appearance. To mitigate this problem, the designer may provide a small wetland marsh or ponding area in the basin’s bottom, which may be considered as part of the design to promote biological uptake of pollutants.

In addition to reducing peak runoff rates and improving water quality, an extended dry detention basin can be designed to provide other benefits such as recreation, wildlife habitat and open space. As with other BMPs, public safety issues need to be addressed through proper design. Extended dry detention basins may also be used during land development to trap sediment from construction activities within the tributary drainage area. The accumulated sediment, however, must be removed after upstream land disturbances cease and before the basin is placed into final long-term use.

5.3.2 Design Considerations

It is imperative to plan land use correctly to account for an extended dry detention basin. The land required for an extended dry detention basin is approximately 0.5 to 2.0 percent of the total tributary development area, depending on directly connected impervious areas and other factors.

Special consideration must be made when placing an extended dry detention basin in an area of high groundwater, wet weather springs or areas that otherwise have baseflow. Consideration should be given to constructing an extended wet detention basin or a wetland bottom in those cases. If an extended dry detention basin is constructed, a low flow channel shall be constructed to maintain positive drainage to allow mowing and maintenance. Sites with persistent flow typically require a special design by a qualified professional for the unique conditions of the site.

Extended dry detention basins should be incorporated into the larger flood control basin whenever possible. In all cases, the embankments and spillway shall be designed to safely pass the 100-year flow as described in Chapter 9, Detention for Flood Control.

When multiple uses such as recreation or habitat creation are incorporated into a detention basin, a multiple-stage design should be used to limit the frequency of inundation of passive recreational areas. Generally, the area within the WQCV is not well suited for active recreation facilities such as ballparks, playing fields, and picnic areas. These are best located above the WQCV pool level.

Soil maps should be consulted, and soil borings may be needed to establish design geotechnical parameters, particularly for larger basins or when bedrock or other sensitive karst features are believed present. A regular concern with storage basins in Springfield is “puncturing” limestone during the course of excavation, thereby providing a conduit for storm water in the shallow groundwater system.

Access to critical elements of the pond, such as the inlet, outlet, spillway, and sediment collection areas must be provided for maintenance purposes.

5.3.3 Design Procedure and Criteria

The following steps outline the design procedure and criteria for an extended dry detention basin. Figure WQ-4 shows a representative layout of an extended dry detention basin.

1. Calculate the design volume, *V*, in cubic feet as follows (a multiplier of 1.25 is applied to account for sediment accumulation):

$$V = WQCV \cdot 1.25 \qquad \text{(Equation WQ-4)}$$

In which:

WQCV = Water Quality Capture Volume, cubic feet (see Section 4.2)

This design volume accounts only for water quality and not for flood control.

2. The basin length to width ratio (L:W) should be between 2:1 and 4:1 and the inlets should be as far as possible from the outlet. Maximizing the distance between the inlet and the outlet and shaping the pond with a gradual expansion from the inlet and a gradual contraction toward the outlet will minimize short-circuiting.

3. Basin side slopes should be a maximum of 4H:1V and the use of flatter slopes is encouraged to facilitate maintenance, access, and safety. If steeper side slopes are necessary, incorporate a flatter upper zone and/or a "safety bench."

4. Determine the preliminary basin geometry necessary to provide the design volume. Select the preferred depth of the extended dry detention basin, then solve for the basin bottom width that will provide adequate storage of the design volume. Assume a trapezoidal pond with the selected L:W ratio, side slopes and basin depth. The extended dry detention basin design form will assist with this calculation. This information is not necessary if detailed stage-area-volume relationships are available for the extended dry detention basin.

5. Design the outlet structure to release the WQCV (not the "design volume" from Step 1) over a 24- to 48-hour period. Outlet structures shall consist of a perforated riser pipe, outlet pipe, and gravel filter material (2-inch clean rock) or a perforated plate with a stainless steel well-screen trash rack. Springfield prefers a perforated plate/well screen due to plugging of gravel filter material but will accept either. Figures WQ-5 and WQ-6 show details for a perforated riser pipe and perforated plate, respectively. If a riser pipe is selected, it shall be connected to an outlet pipe of equal or greater diameter and shall be constructed of Schedule 40 PVC, ductile iron, or corrugated, galvanized metal. Springfield prefers that PVC not be used for durability and maintenance reasons, but will accept PVC if the applicant has a strong preference. A removable cap shall be provided at the top of the riser pipe with a 1-inch hole for air relief. Water quality outlet structures shall meet the requirements in Table WQ-1.

Table WQ-1
Requirements for Water Quality Outlet Structures

Parameter	Perforated Riser Pipe Requirement	Perforated Plate Requirement
Minimum perforation diameter	1/2 inch	1/2 inch
Maximum perforation diameter	1 inch	2 inches
Minimum number of holes per row	4	1
Maximum number of holes per row	8	3
Minimum row spacing	4 inches	4 inches
Maximum row spacing	12 inches	12 inches
Minimum riser pipe diameter	8 inches	n/a

For a riser pipe, select the riser pipe diameter, which must be at least 8 inches. For both riser pipes and perforated plates, select the perforation diameter, number of holes per row, row spacing and total number of rows to meet the requirements in Table WQ-1. Use the fewest number of columns possible to maximize the perforation hole diameter. This helps to reduce clogging problems. The extended dry detention basin design spreadsheet should be used to complete the design.

6. For perforated plates, provide a trash rack of sufficient size to prevent clogging of the primary water quality outlet. Size the rack so as not to interfere with the hydraulic capacity of the outlet. Using the total outlet area (calculated by multiplying the perforation area per row by the number of rows) and the selected perforation diameter, Figure WQ-7 will help to determine the minimum open area required for the trash rack. Use one-half of the total outlet area to calculate the trash rack's size. This accounts for the variable inundation of the outlet orifices. The extended dry detention basin design spreadsheet should be used to complete the design.

7. A freeboard of at least 12 inches shall be provided above the 100-year water surface elevation for all extended dry detention basins (including facilities that are solely for water quality purposes and allow larger flows to "pass through") and detention areas in accordance with Chapter 9, Detention.

8. A low flow channel shall be provided when groundwater or base flow exists in the basin or as required in Chapter 9, Detention.

9. Consideration should be given to the use of native grasses and plants for pond bottoms, berms, and side slopes.

10. Access to the facility shall be provided for maintenance. Grades of the access should not exceed 10 percent, and a stabilized, all-weather driving surface must be provided.

11. Energy dissipation and erosion control should be provided at inlets in accordance with Chapter 9, Detention.

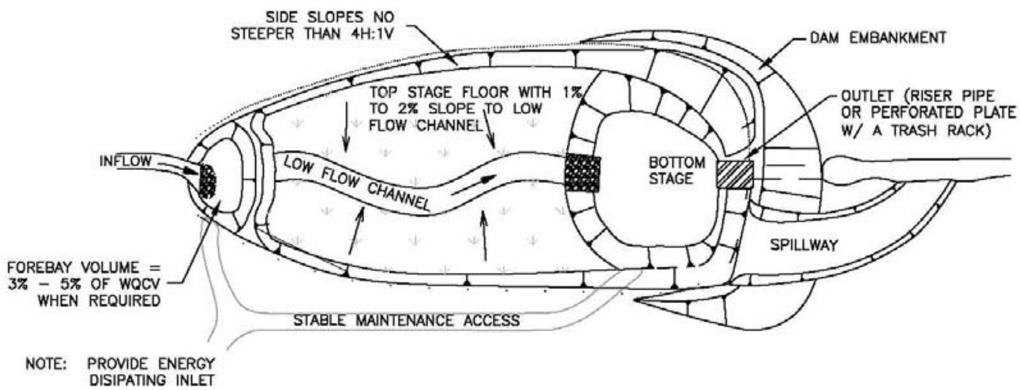
12. A forebay should be considered when the design volume exceeds 20,000 ft^3 or a large sediment, trash or debris load is anticipated due to upstream land use. A forebay provides an opportunity for larger particles to settle out in the inlet area, which has a solid surface bottom to facilitate mechanical sediment removal. The forebay volume for the extended dry detention basin should be between 3 and 5 percent of the design volume. Outflow from the forebay to the basin shall be through a gravel filter designed to be stable under maximum design flow conditions. The top of the gravel filter shall be set equal to the stage of the design volume. The floor of the forebay should be concrete and contain a low flow channel to define sediment removal limits.

13. Combining the water quality facility with a flood control facility is acceptable. Design of the flood control volume may assume the extended dry detention basin is dry at the beginning of the storm. Additional information can be found in Chapter 9, Detention.

14. Plan and design the facility with appearance and neighborhood compatibility as design objectives.

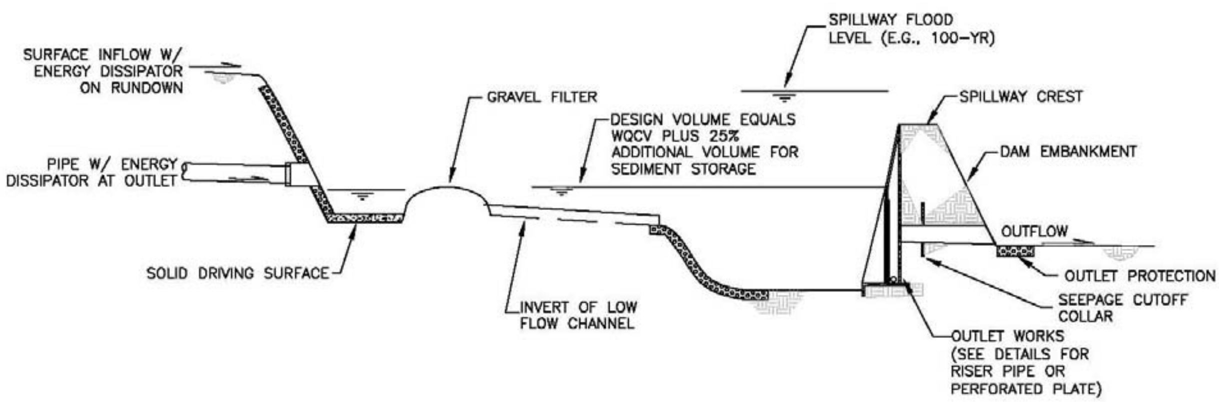
5.3.4 Maintenance

Maintenance should be performed regularly to clean out the extended dry detention basin (or forebay if one is present) when sediment accumulates to a depth of 6 inches. Appearance may dictate more frequent cleaning. Maintenance may also be necessary to repair areas of erosion or to remove sediment clogging the outlet, excessive trash or debris. Design grades must be maintained to ensure shallow ponding does not occur, particularly when within 200 feet of residential areas. Additional maintenance criteria are provided in Chapter 12, Easements and Maintenance.



EXTENDED DETENTION BASIN PLAN

NTS



EXTENDED DETENTION BASIN PROFILE

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EXTENDED DETENTION BASIN

FIGURE 1 OF 4

Figure WQ-4
Plan and Profile of an Extended Detention Basin

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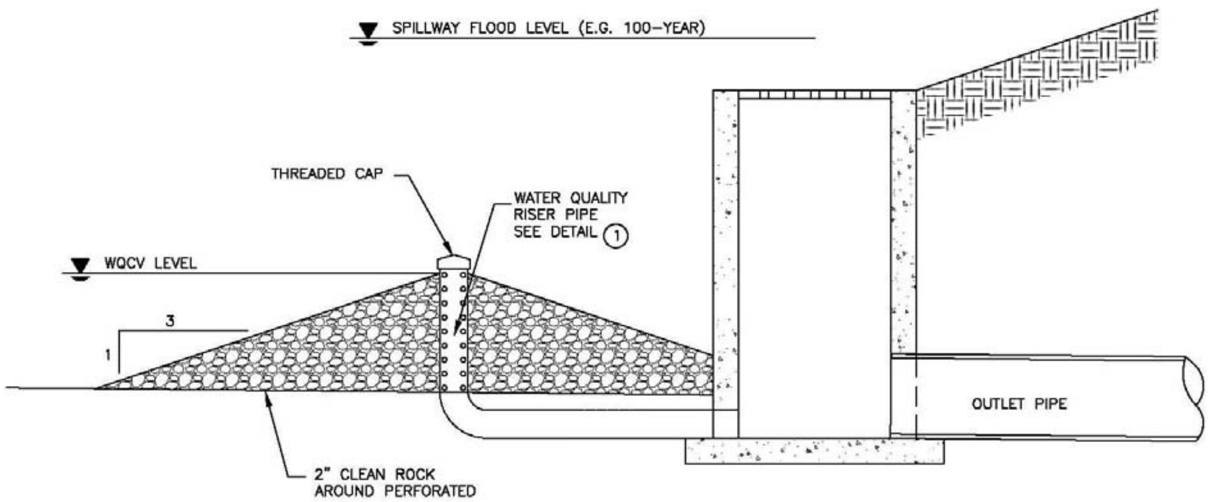

RISER PIPE OUTLET
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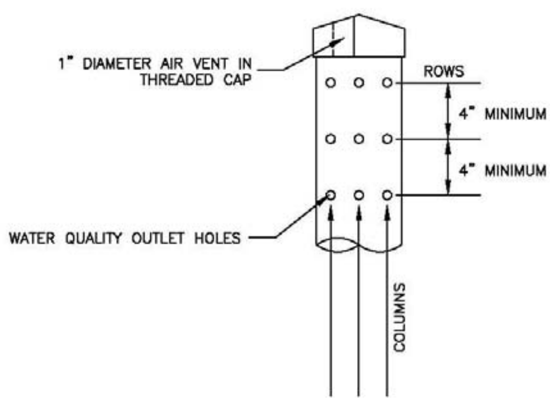

RISER PIPE OUTLET DETAIL 1
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RISER PIPE OUTLET

Figure WQ-5
Details for a Perforated Riser Pipe

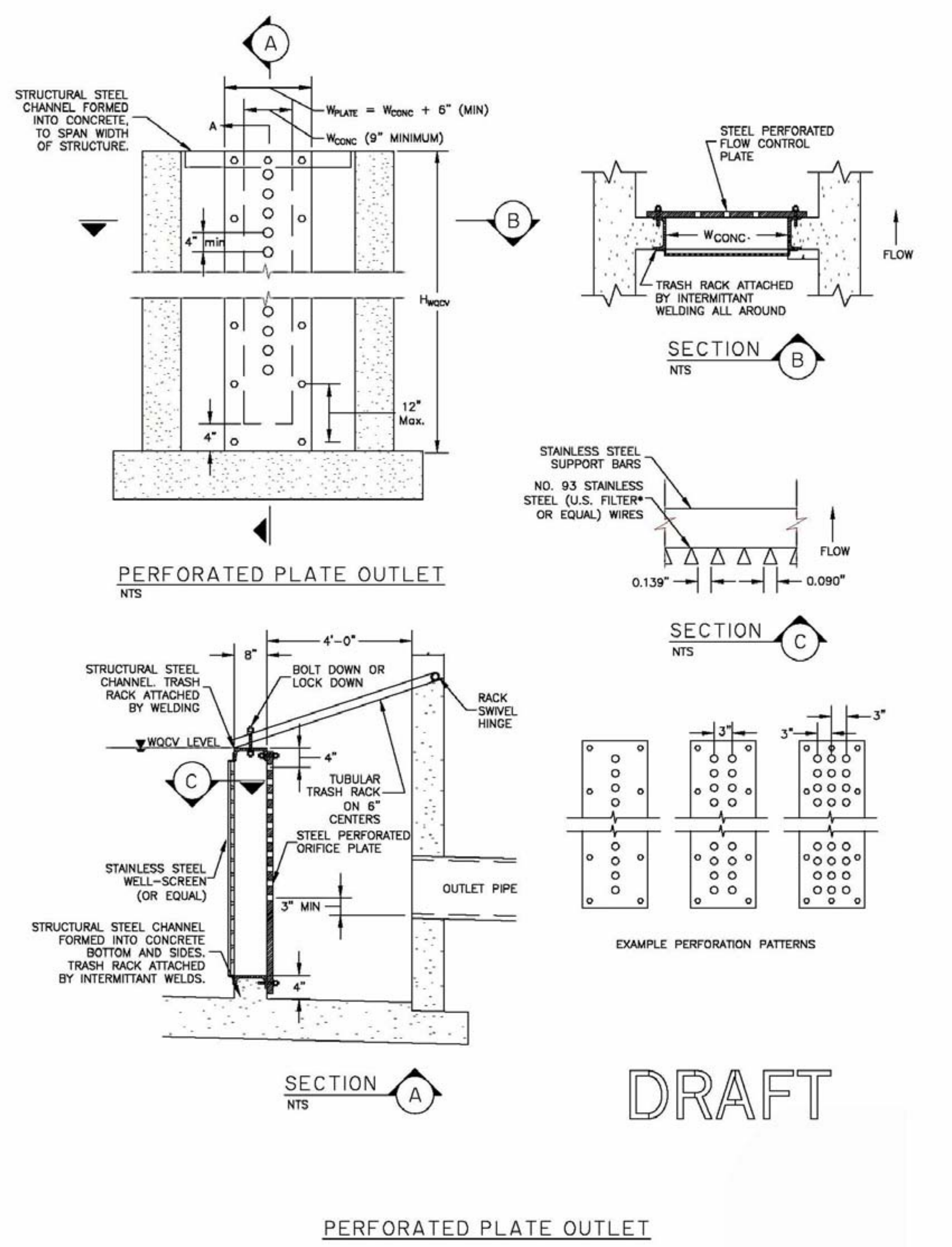

Figure WQ-6
Details for a Perforated Plate and Trash Rack

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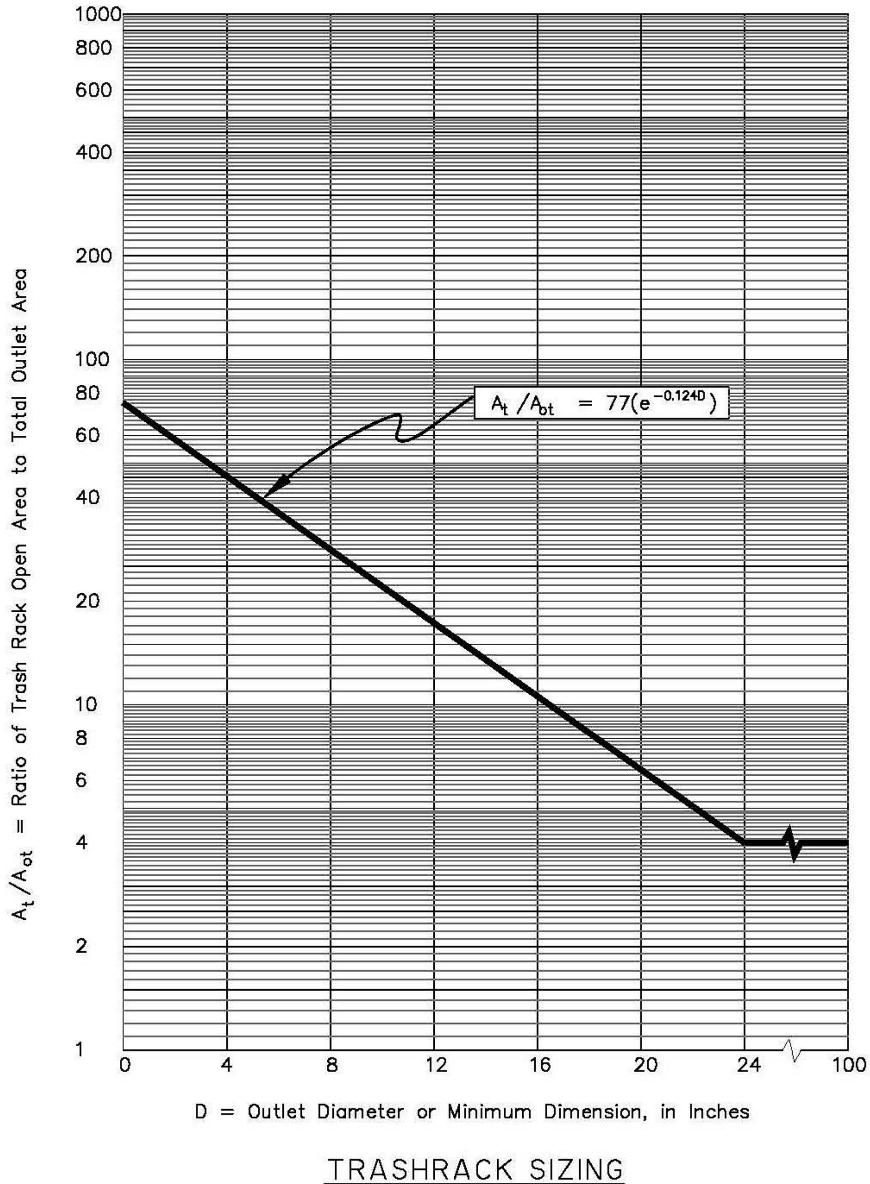


Figure WQ-7
Trash Rack Sizing

5.3.5 Design Example

The following example demonstrates use of the Extended Detention Basin (EDB) Worksheet in the SF-BMP Spreadsheet to determine xxx. DETAILS TO BE DETERMINED

Data Input (for EDB)

Results (for EDB)

Insert Image of Completed Spreadsheet for EDB Here

5.4 Extended Wet Detention Basins

5.4.1 Description

Similar to an extended dry detention basin, an extended wet detention basin is designed to collect the runoff from smaller, more frequent rainfall events and release the runoff over a longer period of time. The design collects and treats the "first flush" runoff, which typically has a higher concentration of most pollutants found in urban runoff. Like an extended dry detention basin, an extended wet detention basin can be used for regional or on-site treatment or as follow-up treatment in series with other BMPs. Unlike an extended dry detention basin, an extended wet detention basin is designed with a permanent pool, which provides water quality benefits as the influent water mixes with the permanent pool water and most of the sediment deposits remain in the permanent pool zone. An extended wet detention basin provides a similar level (or better due to the permanent pool) of water quality treatment as compared to an extended dry detention basin, but in less time because the outflow occurs above the bottom of the basin and sedimentation continues after the captured surcharge volume is emptied.

An extended wet detention basin should be designed with the WQCV above the permanent pool, and the outlet structure should be sized to drain the WQCV in approximately 12 to 15 hours. The reduced drain time (when compared to the extended dry basin) is due to the permanent pool. Flood control volume may also be provided above the permanent pool by including modified outlet controls, a 100-year (minimum) overflow spillway and a minimum of 1 foot of freeboard above the 100-year water surface.

Extended wet detention basins can be very effective in removing pollutants and, when properly designed and maintained, can satisfy multiple objectives such as the creation of wildlife habitats; provision of recreational, aesthetic, and open space opportunities; and inclusion into a larger, regional flood control basin. An extended wet detention basin must be carefully designed and maintained to address safety concerns, bank erosion, sediment removal, and upstream and downstream impacts to waterways. In addition, extended wet detention basins have the potential for floating litter, debris, algae growth, nuisance odors, and mosquito problems. Aquatic plant growth can be a factor in clogging outlet works, and the permanent pool can attract waterfowl, which can add to the nutrient and bacteria loads entering and leaving the pond.

Refer to Chapter 9, Detention and Chapter 12, Easements and Maintenance for additional design criteria.

5.4.2 Design Considerations

The total basin volume of an extended wet detention basin facility consists of the permanent pool volume, the WQCV above the permanent pool and, if included, the flood control volume above the WQCV. Care should be taken to assess the complete water budget of the watershed accounting for runoff, baseflow, evaporation, evapotranspiration, seepage, and other losses to assure the permanent pool can be maintained.

Design considerations for an extended wet detention basin in addition to the considerations typically given to an extended dry detention basin include:

- Water balance calculations should be conducted to assure there is adequate flow to maintain a desirable permanent pool and provide adequate flushing through the basin.
- Edge treatments must be considered that will prevent bank erosion.
- To minimize the potential of algae growth, a minimum permanent pool depth of 6 feet must be provided. Other control methods including aeration or upstream BMPs may also be provided.
- Basin lining must be provided to ensure the basin is watertight and a permanent pool will be maintained – karst features can make this difficult and expensive.
- The embankments must be carefully designed with keys and cutoff collars to prevent seepage and piping that can lead to loss of the permanent pool or dam failure.
- A shorter detention time of 12 to 15 hours may be used due to the inherent sedimentation that occurs in a wet basin.

5.4.3 Design Procedure and Criteria

The following steps outline the design procedure and criteria for an extended wet detention basin. Figure WQ-8 shows a representative layout for an extended wet detention basin.

1. For large ponds, if the residence time for the permanent pool volume is 24 hours or greater during a 2-year storm event, the surcharge WQCV is not required above the permanent pool. The residence time, t (hr), is calculated by dividing the permanent pool volume, V_p (ft^3), by the average inflow rate during a 2-year storm event, $Q_{2yr,\ avg}$ (cfs), as shown in Equation WQ-5. The 2-year average inflow rate must be calculated using the appropriate hydrologic analysis method presented in Chapter 5, Calculation of Runoff.

$$t = \frac{V_p}{Q_{2yr-avg} \cdot 3600} \qquad \text{(Equation WQ-5)}$$

2. If the residence time is less than 24 hours, the WQCV shall be added above the permanent pool and shall be calculated using the method provided in Section 4.2 of this chapter. The WQCV is the surcharge volume above the permanent pool. Generally, an extended wet detention basin should be located away from any offsite drainage crossing the site to ensure proper function. If offsite area is drained through the facility, that area must be included in all volume calculations.

3. The minimum volume required for the permanent pool is a function of the WQCV and is calculated using Equation WQ-6.

$$V_p = 1.2 \cdot WQCV \qquad \text{(Equation WQ-6)}$$

   The permanent pool shall have a depth of at least 6 feet (and preferably deeper) to decrease the likelihood of algae growth. An option to improve water quality treatment and minimize bank erosion is to provide a littoral zone 18 inches deep and 10 feet wide for aquatic plant growth along the perimeter of the permanent pool. This also enhances pond safety.

4. The outlet works are to be designed in accordance with requirements set forth in Section 5.3.3, Design Procedure and Criteria for an extended dry detention basin, with the following exceptions:

   a. Design the outlet works to release the WQCV over a 12- to 15-hour period.

   b. Where perforated riser pipes are not encased in gravel, only corrugated metal or ductile iron pipe may be used, and an anti-seep collar must be provided around the outlet.

5. The trash rack is to be designed in accordance with requirements set forth in Section 5.3.3, Design Procedure and Criteria for an extended dry detention basin.

6. The basin length to width ratio should be between 2:1 and 4:1. The minimum allowable ratio is 1:1. Maximizing the distance between the inlet and the outlet will minimize short-circuiting.

7. Basin side slopes above the permanent pool should be no steeper than 4:1, preferably 5:1 or flatter to limit rill erosion and facilitate maintenance and safety.

8. A 4- to 6-inch organic topsoil layer, vegetated with aquatic species, shall be provided on the littoral bench if incorporated.

9. Access to the basin bottom, forebay, and outlet area must be provided for maintenance vehicles. Grades of the access should not exceed 10 percent, and a stabilized, all-weather driving surface must be provided.

10. Provide erosion protection at all inlets to the pond.

11. A forebay should be considered when the design volume exceeds 20,000 ft^3 or a large sediment, trash or debris load is anticipated due to upstream land use. Forebays provide an opportunity for larger particles to settle out at a controlled location where sediment and debris can be more easily removed. Install a solid driving surface on the bottom and sides below the permanent water line to facilitate sediment removal. A berm consisting of rock and topsoil mixture should be part of the littoral bench to create the forebay. The forebay volume within the permanent pool volume should be between 5 and 10 percent of the design WQCV.

5.4.4 Maintenance

Intermittent maintenance may be necessary to remove floating trash, debris and algae from the surface of the permanent pool. Chemical treatments may be necessary to control algae growth. It may also be necessary to remove accumulated sediments from the pond bottom on a regular basis. A maintenance plan shall be developed that adheres to these minimum criteria and shall be recorded as part of subdivision covenants. Additional maintenance criteria are provided in Chapter 12, Easements and Maintenance.

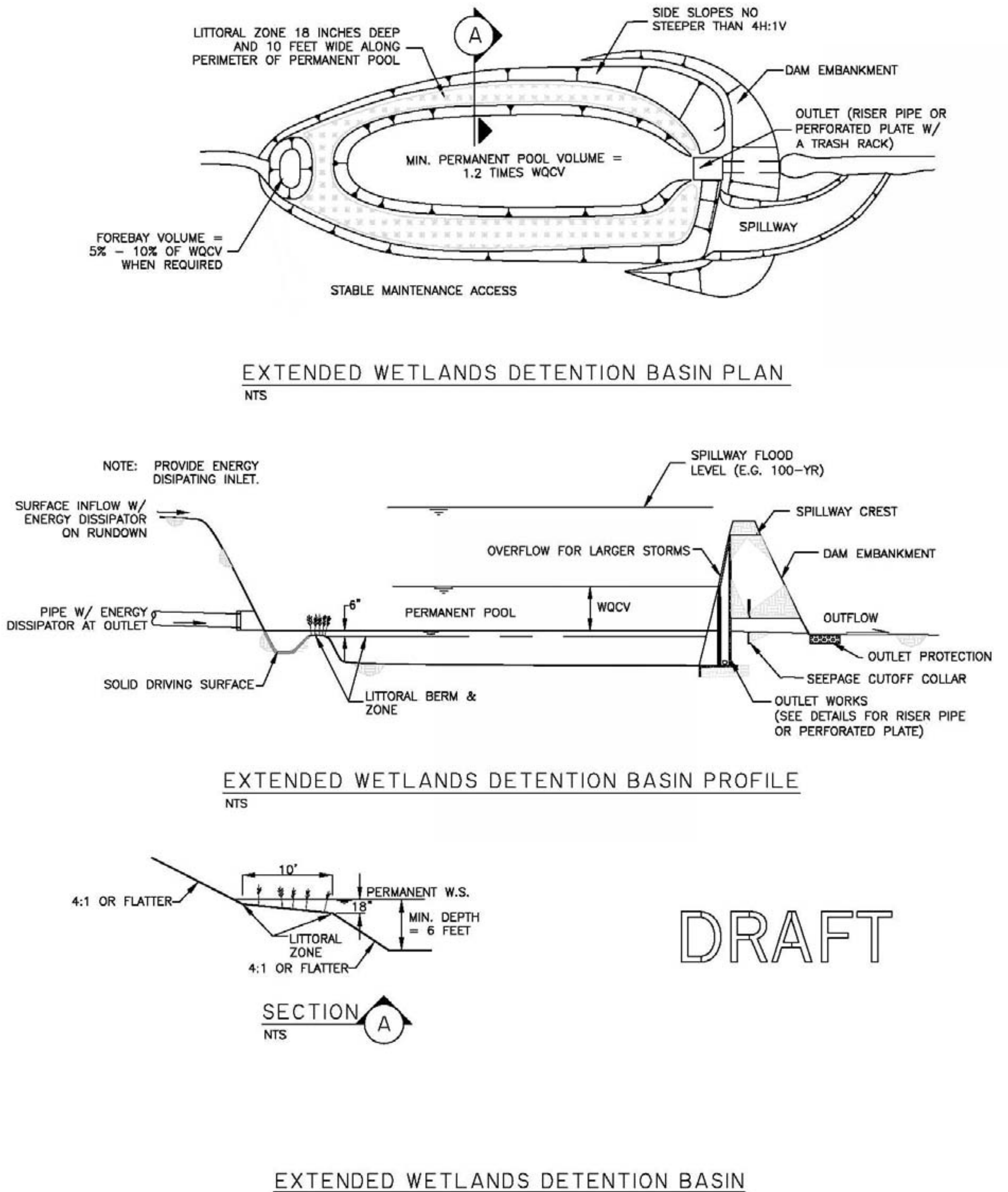


Figure WQ-8
Plan, Profile and Details of an Extended Wet Detention Basin

5.4.5 Design Example

The following example demonstrates use of the Extended Wet Detention Basin (EWDB) Worksheet in the SF-BMP Spreadsheet to xxx. DETAILS TO BE DETERMINED

Data Input (for EWDB)

Results (for (EWDB)

INSERT IMAGE OF COMPLETED SPREADSHEET FOR (EWDB) HERE

5.5 Constructed Wetland Basin

5.5.1 Description

A constructed wetland basin is a shallow extended wet detention basin that requires a perennial base flow to maintain microorganism habitat and to permit the growth of rushes, willows, cattails, and reeds to slow runoff and allow time for sedimentation, filtering, and biological uptake. Existing small wetlands along ephemeral drainageways in Missouri could be enlarged and incorporated into a constructed wetland system. Such action, however, requires the approval of federal and state regulators.

When properly designed, a constructed wetland basin can offer several potential advantages, such as natural aesthetic qualities, wildlife habitat, erosion control, and pollutant removal. Additionally, the constructed wetland basin can act as part of a multi-use facility by providing flood control storage above the WQCV pool or by providing effective follow-up treatment to onsite and source control BMPs that rely upon settling of larger sediment particles.

The primary drawback of the constructed wetlands basin is the need for a continuous base flow to ensure viable wetland growth. In addition, silt and algae can accumulate and, unless properly designed and built, can be flushed out during larger storms, reducing downstream water quality benefits. Also, in order to maintain healthy wetland growth, the surcharge depth for WQCV above the permanent water surface cannot exceed roughly 2 feet.

5.5.2 Design Considerations

Development and analysis of a water budget is needed to show the net inflow of water is sufficient to meet all the projected losses (such as evaporation, evapotranspiration, and seepage for each season of operation) and ensure a perennial baseflow. Insufficient inflow can cause the wetland to become saline or die.

Loamy soils are needed in a wetland bottom to permit plants to take root. Exfiltration through a wetland bottom cannot be relied upon because the bottom is either covered by soils of low permeability or because the groundwater is higher than the wetland's bottom. Also, wetland basins require a near-zero longitudinal slope, which can be provided using embankments.

5.5.3 Design Procedure and Criteria

The following steps outline the design procedure for a constructed wetland basin. Figure WQ-9 illustrates an idealized constructed wetland basin.

1. Calculate the WQCV in cubic feet using the method described in Section 4.2. The WQCV is the surcharge volume above the permanent wetland pool.

2. The volume of the permanent wetland pool shall be no less than 75 percent of the WQCV.

3. Proper distribution of wetland habitat is needed to establish a diverse plant community. Distribute pond area in accordance with Table WQ-2.

Table WQ-2
Wetland Pond Water Design Depths

Components	% of Permanent Pool Surface Area	Water Design Depth
Forebay, outlet and free water surface areas	30% to 50%	2 to 4 feet deep
Wetland zones with emergent vegetation	50% to 70%	6 to 12 inches deep*

* One-third to one-half of this zone should be 6 inches deep.

4. The surcharge depth of the WQCV above the permanent pool's water surface shall not exceed 2.0 feet.

5. The outlet works shall be designed in accordance with requirements set forth for extended dry detention basins in Section 5.3.3, with the following exceptions:

   a. Design the outlet works to release the WQCV in 22 to 28 hours.

   b. Where perforated riser pipes are not encased in gravel, only corrugated metal or ductile iron pipe may be used, and an anti-seep collar must be provided around the outlet pipe.

   c. Outlet design should consider the elevated potential for wetland vegetation growth and clogging around the outlet.

6. The trash rack shall be designed in accordance with requirements set forth for extended detention basins in Section 5.3.3.

7. Determine whether flood storage or other uses will be provided and design accordingly for combined uses.

8. The basin length to width ratio should be between 2:1 and 4:1. The minimum allowable ratio is 1:1. Maximizing the distance between the inlet and the outlet will minimize short-circuiting.

9. Basin side slopes should be no steeper than 4:1, preferably 5:1 or flatter to facilitate maintenance, safety and access.

10. A net influx of water must be available through a perennial base flow and must exceed the losses. A hydrologic balance should be used to estimate the net quantity of base flow available at a site.

11. Provide energy dissipation at all inlets to limit sediment resuspension.

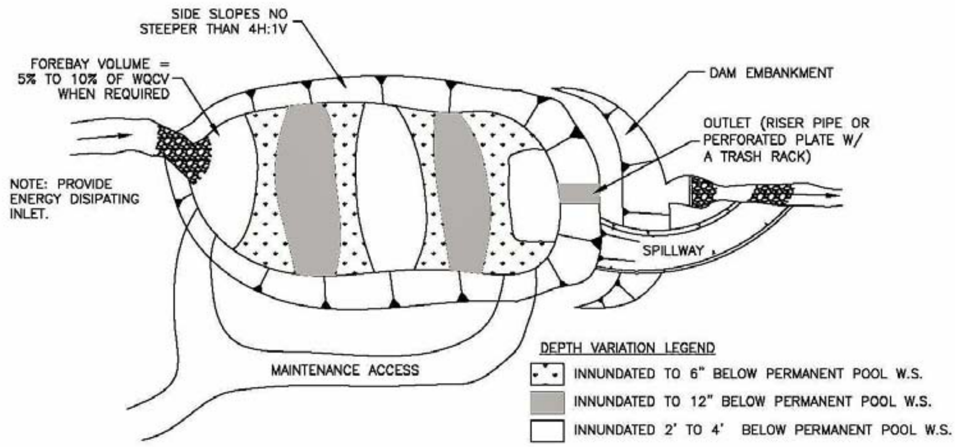
12. Forebay design considerations and criteria for extended wet detention basins in Section 5.4.3 shall be followed.

13. Cattails, sedges, reeds, and wetland grasses should be planted in the wetland bottom. Qualified professionals must be utilized to develop the planting plan and to plant the wetland plants. Berms and side-slopes should be planted with native or turf-forming grasses. Initial establishment of the wetland requires control of the water depth. After planting wetland species, the permanent wetland pool should be kept at 3 to 4 inches deep at the plant zones to allow growth and to help establish the plants, after which the pool should be raised to its final operating level.

14. Provide vehicle access to the forebay and outlet area for maintenance and removal of bottom sediments. Maximum grades should not exceed 10 percent, and a stabilized, all-weather driving surface must be provided.

5.5.4 Maintenance

Along with routine maintenance, occasional “mucking out” will be required when sediment accumulations become too large and affect performance. This may be required whenever sediment accumulation occupies approximately 20 percent of the WQCV. Periodic sediment removal is also needed for proper distribution of growth zones and water movement within the wetland. Additional maintenance criteria are provided in Chapter 12, Easements and Maintenance.



EXTENDED WETLANDS DETENTION BASIN PLAN

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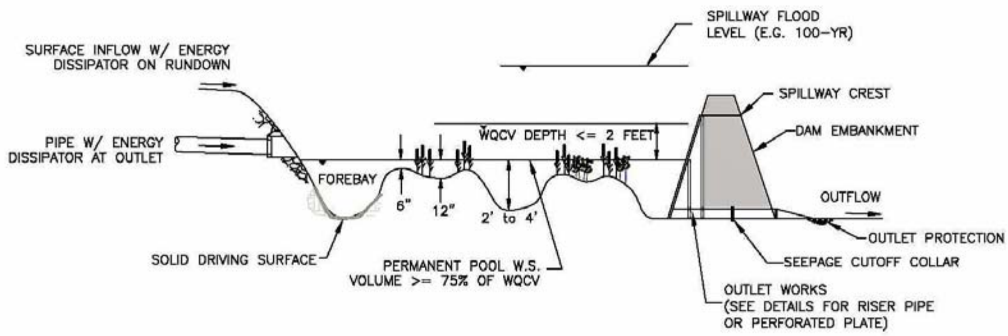

CONSTRUCTED WETLANDS BASIN PROFILE

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CONSTRUCTED WETLANDS BASIN

Figure WQ-9
Plan and Profile of an Idealized Constructed Wetland Basin

5.5.5 Design Example

The following example demonstrates use of the Constructed Wetland Basin (CWB) Worksheet in the SF-BMP Spreadsheet to determine xxx. DETAILS TO BE DETERMINED

Data Input (for CWB)

Results (for CWB)

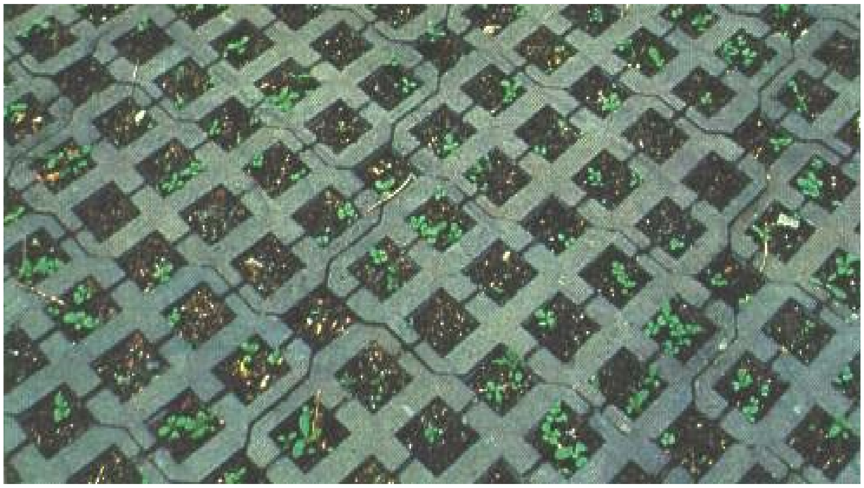
INSERT IMAGE OF COMPLETED SPREADSHEET FOR (CWB) HERE

5.6 Modular Block Porous Pavement

5.6.1 Description

Modular block porous pavement consists of open void concrete block units laid on a gravel sub-grade. The surface voids are filled with sand or sandy loam turf. An alternate approach is to use reinforced grass porous pavement, consisting of grass turf reinforced with plastic rings and filter fabric underlain by gravel. Modular block porous pavement is intended for use in low vehicle movement areas such as residential driveways and parking pads to accommodate vehicles while facilitating storm water infiltration from rain falling directly on the porous pavement. Modular block porous pavement can also be used for crossover/emergency stopping/parking lanes on divided highways, residential street parking lanes, maintenance roads and trails, emergency vehicle and fire access lanes in apartment/multi-family/office complex situations and low vehicle movement airport zones such as parking aprons and maintenance roads. The modular block porous pavement should be mildly sloped, but not completely flat, to decrease the effective imperviousness of a site without creating standing water problems. The modular block porous pavement can be considered to reduce the imperviousness over the installation area by approximately 25 percent, depending on the exact void ratio of the block.

Aside from the potential for high particulate pollutant removal and the removal of other constituents similar to a sand filter application, modular block porous pavement can reduce flooding potential by infiltrating or slowing down runoff. Modular block patterns, colors, and materials can serve both functional and aesthetic purposes.



The primary disadvantages for use of modular block porous pavement are cost and the lack of performance data in areas that are subject to severe freeze-thaw cycles; however, existing data and observations indicate that modular block porous pavement functions well in freeze-thaw cycles when properly designed and installed. Other disadvantages could be associated with uneven driving surfaces and potential traps for high-heeled shoes. Also, the cost of restorative maintenance can be somewhat high when the system seals with sediment.

5.6.2 Design Considerations

Modular block porous pavement must be installed with a free draining sub-grade or an underdrain system to ensure drainage of the gravel sub-grade. This BMP may not be used at industrial, transportation or similar sites where chemical or petroleum spills are a possibility.

Vehicle movement (i.e., not parking) lanes that lead up to the modular block porous pavement need to be solid asphalt or concrete pavement.

Multiple block patterns are acceptable provided they have at least 20 percent (40 percent preferred) of the surface area as voids. Upon installation, every effort should be made to assure even flow distribution over the entire porous surface. The pervious area is generally assumed equal to the surface void area of the modular block.

5.6.3 Design Procedure and Criteria

The following steps outline the modular block porous pavement design procedure and criteria. Figure WQ-10 shows cross-sections of modular block installation and its sub-grade. Figure WQ-11 depicts typical applications of modular block porous pavement.

1. Select appropriate modular blocks that have no less than 20 percent (40 percent preferred) of the surface area open and have a minimum thickness of 4 inches. The manufacturer's installation

requirements shall be followed with the exception that Rock Media Pore Volume Inlay Material and Base Course minimum dimensions and requirements in this section shall be followed.

2. The modular block porous pavement openings should be filled with ASTM C-33 graded sand (fine concrete aggregate) and should be placed on a 1-inch-thick leveling course of the sand.

3. The base course shall be AASHTO No. 3 coarse aggregate for all fractured surfaces with a minimum depth of 8 inches. For volume calculations, assume 30 percent of total volume to be open pore space. Unless an underdrain is provided, at least 6 inches of the sub-grade underlying the base course shall be sandy and gravely material with no more than a 10 percent clay fraction.

4. Place a woven geotextile fabric *over* the base course as shown in Figure WQ-10. Use a geotextile material that meets the following requirements: ASTM D-4751 – AOS U.S. Std. Sieve #50 to #70 and D-4632 – Trapezoidal tear strength ≥ 100 x 60 lbs; with U.S. Army Corps of Engineers (USACE) specified minimum open area ≥ 4 percent.

5. If the contributing drainage area is a land use with potential activities that store, manufacture or handle fertilizers, chemical or petroleum products, install an uninterrupted and puncture free 16-mil polyethylene or PVC impermeable membrane and provide an underdrain system *under* the base course. Otherwise, to permit infiltration, use a geotextile material that meets the ASTM requirements listed under item 4, above.

6. Place geotextile fabric and impermeable membrane by rolling fabric parallel to the contours, starting at the most downstream part of the pavement. Provide a minimum of 18 inches overlap between adjacent sheets. Bring up geotextile and impermeable membrane to within 1 inch of the top of the perimeter walls. Attach membrane and fabric to walls with roofing tar or other adhesive. Seal all joints of impermeable membrane to be totally leak free.

7. The design area ratio of contributing impervious area to porous pavement area shall not exceed 2.

8. If a concrete perimeter wall is provided, it should confine the edges of the modular block porous pavement block area. The wall should be minimum of 6-inches wide and 12 inches deeper than all the porous media and modular block depth combined (see Figure WQ-10).

9. Provide 16-mil or thicker polyethylene or PVC membrane liner placed vertically or concrete walls to separate individual cells of the porous base course to cut-off horizontal flow of water (see Figure WQ-10). Space these cut-off barriers according to the following equation:

$$L_{MAX} = \frac{D}{1.5S_o}$$ (Equation WQ-7)

in which:

L_{MAX} = Maximum distance between cut-off membrane normal to the flow (feet)

S_O = Slope of the base course (ft/ft)

D = depth of gravel base course (feet)

10. When necessary, install 4-inch underdrains at the bottom of the coarse aggregate layer. Underdrains shall be spaced at a maximum of 20 feet with a minimum slope of 0.2 percent. Underdrains shall connect to an existing storm sewer or daylight to an appropriate storm water drainage conveyance.

5.6.4 Maintenance

The sand filling the voids within the concrete block pavement will need to be replaced when clogging is evident. Intermittent repairs to the modular blocks may be necessary due to potential for breakage or displaced blocks caused by heavy machinery or trucks on the modular block porous pavement. Additional maintenance criteria are provided in Chapter 12, Easements and Maintenance.

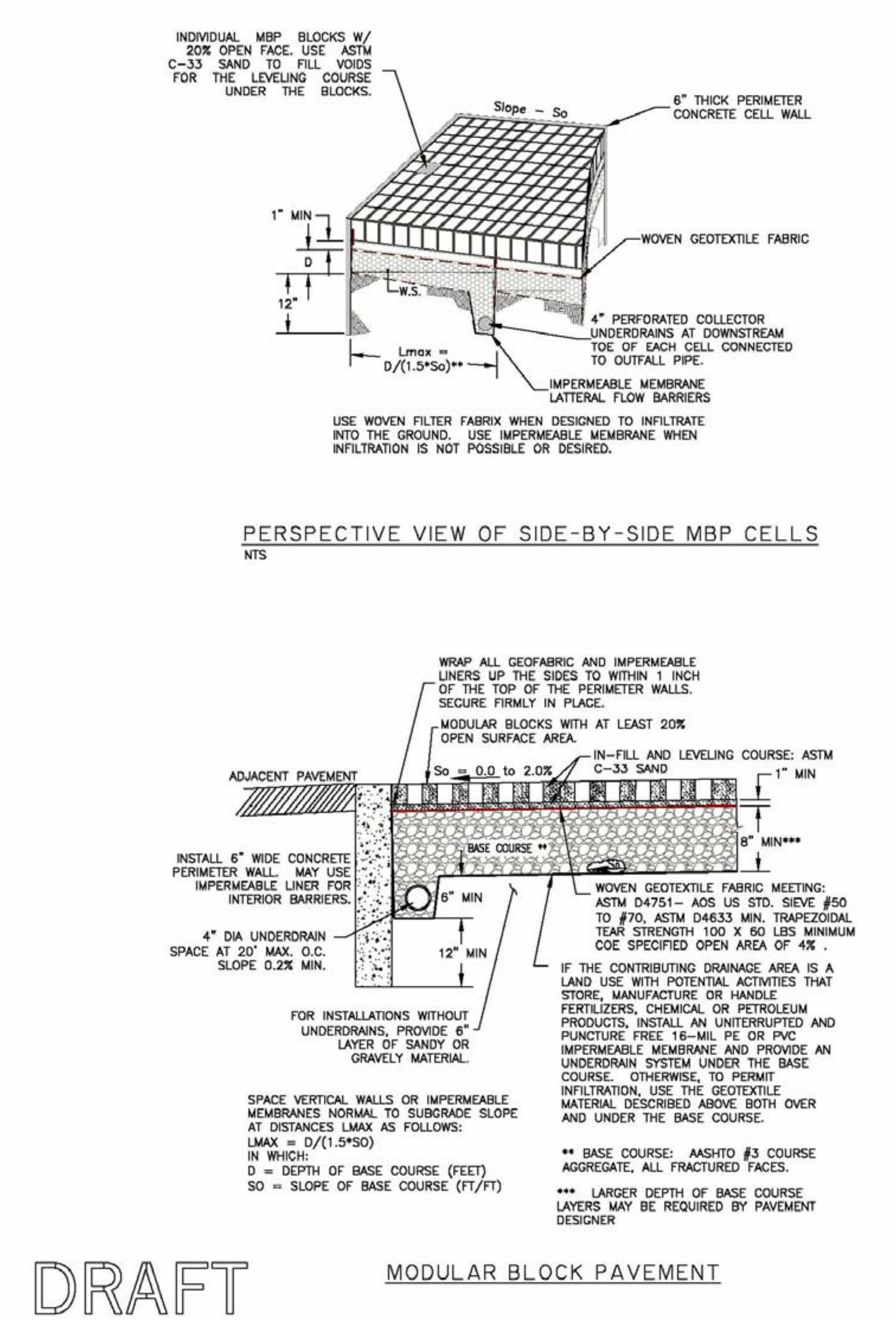


Figure WQ-10
Modular Block Porous Pavement

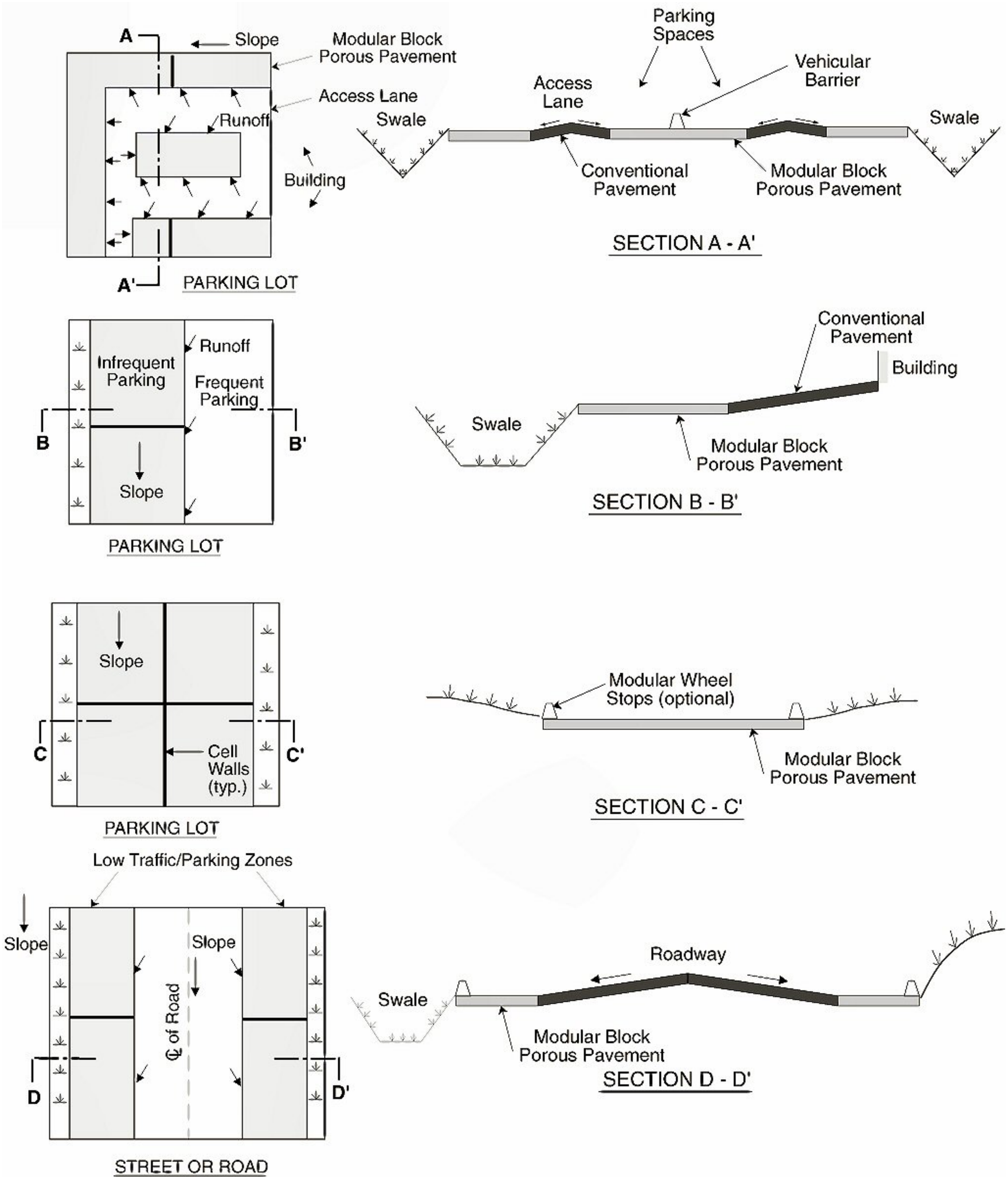


Figure WQ-11
Typical Applications of Modular Block Porous Pavement

5.6.5 Design Example

The following example demonstrates use of the Modular Block Porous Pavement (MBP) Worksheet in the SF-BMP Spreadsheet to determine xxx. DETAILS TO BE DETERMINED

Data Input (for MBP)

Results (for MBP)

INSERT IMAGE OF COMPLETED SPREADSHEET FOR (MBP) HERE

5.7 Porous Landscape Detention

5.7.1 Description

Porous landscape detention consists of a low-lying vegetated area underlain by a porous media bed with an underdrain pipe, which gradually dewaters the porous media bed and discharges the runoff to a nearby channel, swale, or drainage system. A shallow surcharge zone exists above the porous landscape detention for temporary storage of the WQCV. During a storm, accumulated runoff ponds in the vegetated zone and gradually infiltrates into the underlying porous media bed.

Porous landscape detention is ideally suited for small installations such as parking lot islands, street medians, roadside swale features, and site entrance or buffer features. This BMP may also be implemented at a larger scale, serving as an infiltration basin for an entire site, provided the WQCV and average depth requirements contained in this section are met. Vegetation may consist of turfgrass or natural grasses with shrub and tree plantings. A porous landscape detention provides a natural moisture source for vegetation, enabling “green areas” to exist with reduced irrigation.

The primary disadvantage of porous landscape detention is the potential for clogging if moderate to high quantities of silts and clays are allowed to flow into the facility. Also, this BMP should be avoided close to building foundations, although an underdrain and impermeable liner can address the concern of saturation, shrink and swell near a foundation. Additionally, this BMP has a relatively flat surface area and may be difficult to incorporate into steeply sloping terrain.

5.7.2 Example Applications

The photograph below shows an example of a relatively large porous landscape detention facility featuring a dense turfgrass bottom with a putting green.

5.7.3 Design Considerations

When implemented using multiple small installations on a site, it is important to accurately account for each upstream drainage area tributary to each porous landscape detention site to make sure that each facility is properly sized for the tributary area.

5.7.4 Design Procedure

The following steps outline the porous landscape detention design procedure and criteria. Figure WQ-12 shows a cross-section for a porous landscape detention.

1. Calculate the WQCV in cubic feet based on Section 4.2 of this chapter. The storage volume equals the WQCV.

2. Calculate the minimum required surface area, A_s (ft^2), as follows:

$$A_S = \frac{WQCV}{d_{av}} \qquad \text{(Equation WQ-8)}$$

   In which:

   d_{av} = average depth of the porous landscape detention basin (6-inch minimum, 12-inch maximum)

3. Provide a minimum 18-inch layer of well-mixed sand and peat (2/3 sand and 1/3 peat) for plant growth as shown in Figure WQ-12. Do not use compost. Keep the top surface as flat as possible, while avoiding side slopes steeper than 4:1.

Install an 8-inch layer of granular sub-base with all fractured faces meeting the requirements of AASHTO #3 coarse aggregate. Install 4-inch underdrains at the bottom of the granular layer. Underdrains should be spaced at a maximum of 20 feet with a minimum slope of 0.2 percent. Underdrains should connect to an existing drainage system or daylight to an appropriate storm water drainage channel.

4. Use porous geotextile fabric to line the entire basin bottom and sides.

5.7.5 Maintenance

Periodic maintenance will be necessary for the landscaping in the porous landscape detention. Eventually, a porous landscape detention will require cleanout and replacement of the porous media. If a high level of silts and clays are allowed to flow into the facility, the porous media may become clogged and require replacement more often. Use and periodic replacement of at least 3 inches of mulch on the surface can help prevent porous media clogging and is relatively easy to maintain. Additional maintenance criteria are provided in Chapter 12, Easements and Maintenance. The Low Impact Development Center website (www.lowimpactdevelopment.org) provides additional design and maintenance recommendations for bioretention cells, which are comparable to porous landscape detention.

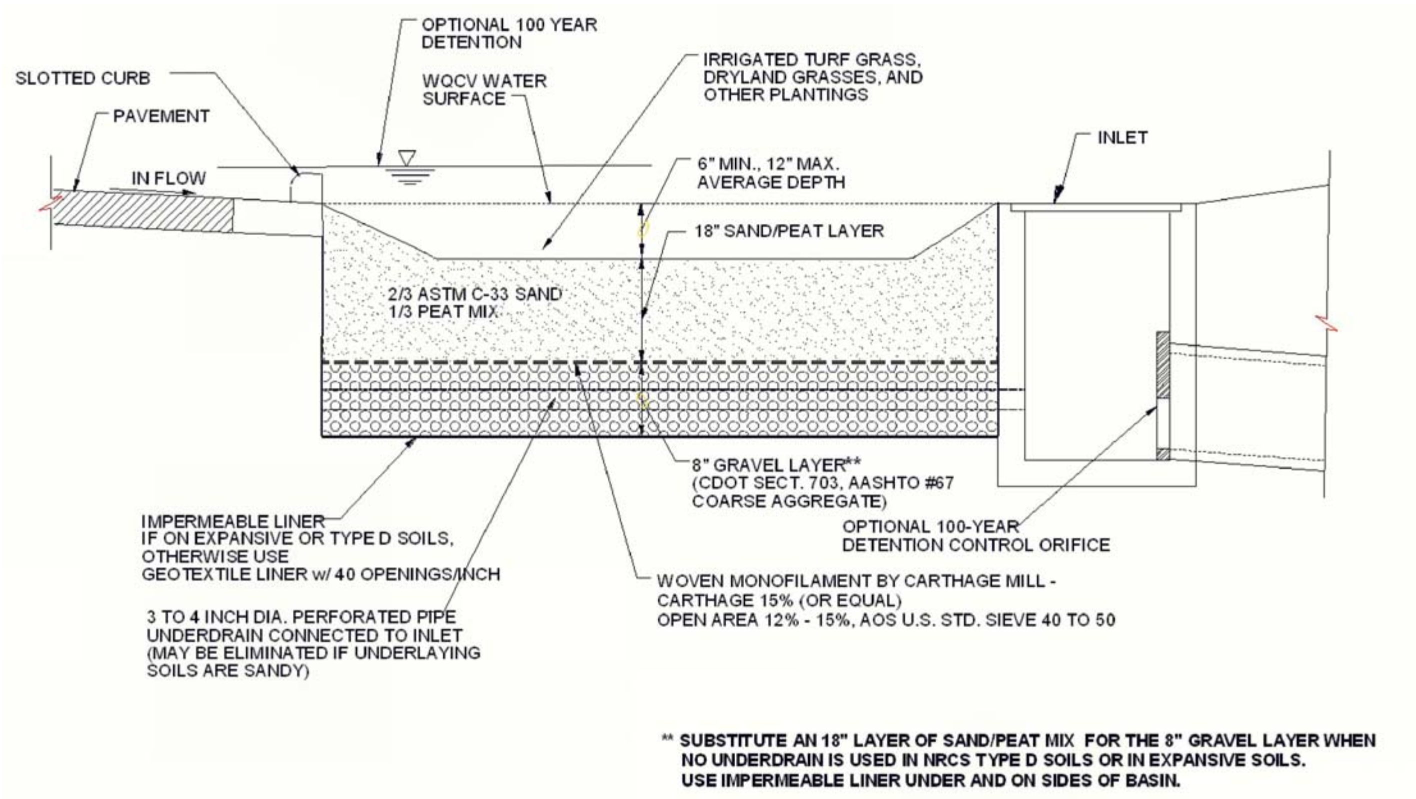


Figure WQ-12
Porous Landscape Detention

5.7.6 Design Example

The following example demonstrates use of the Porous Landscape Detention (PLD) Worksheet in the SF-BMP Spreadsheet to determine xxx. DETAILS TO BE DETERMINED

Data Input (for PLD)

Results (for PLD)

INSERT IMAGE OF COMPLETED SPREADSHEET FOR (PLD) HERE

5.8 Covering of Storage/Handling Areas

Covering of storage and handling facilities and proper handling of potential industrial or commercial pollutants, such as salt piles, oil products, pesticides, fertilizers, etc., is a requirement under Springfield's storm water MS4 discharge permit (Appendix C). In addition, these practices reduce the likelihood of storm water contamination and help prevent loss of material from wind or rainfall erosion. Development plans for these facilities must specify how potential pollutants will be covered and handled to prevent discharge of the pollutant into the City's MS4. Covering is appropriate for areas where solids (e.g., gravel, salt, compost, building materials, etc.) or liquids (e.g., oil, gas, tar, etc.) are stored, prepared, or transferred. Coverings should be permanent in nature and handling procedures must be carried through plans and policies in place at the operating facility.

5.9 Spill Containment and Control

Spill containment within industrial and some commercial sites includes berms, walls and gates that control spilled material. Berms consist of temporary or permanent curbs or dikes that surround a potential spill

site, preventing spilled material from entering surface waters or storm sewer systems. The berm or wall may be made of concrete, earthen material, metal, synthetic liners, or any material that will safely contain the spill. The containment area must have an impermeable floor (asphalt or concrete) or liner so that contamination of groundwater does not occur.

Two methods of berming can be used: 1) containment berming that contains an entire spill, or 2) curbing that routes spill material to a collection basin. Both methods should be sized to safely contain a spill from the largest storage tank, rail car, tank truck, or other containment device located inside the possible spill area. A collection basin should be provided to hold storm water and spills until removal is possible.

5.10 Alternative Structural BMPs

Site conditions may be conducive to the use of alternative BMPs such as proprietary packaged storm water treatment units. Site conditions may include limited space in an ultra-urban or redevelopment setting, a sensitive receiving water or feature, a site with a high pollutant discharge potential, etc. All proposed units of this type must be reviewed and accepted by the City prior to installation.

6.0 LOW IMPACT DEVELOPMENT

Low Impact Development (LID) is an overall development approach that is designed to mimic a site's predevelopment hydrology. The major components of LID include:

1. Conservation and protection of site features such as streams, wetlands, and valuable habitat areas and avoidance of potential problem areas such as steep slopes.

2. Minimization of site impacts by minimizing clearing and grading, preserving soils with high infiltration capacities (Type A and B soils), limiting lot disturbance, incorporating soil amendments, disconnecting impervious surfaces, and reducing impervious surfaces.

3. Maintaining the natural time of concentration to the extent practicable through use of open drainages, incorporating green spaces, flattening slopes, dispersing drainage, lengthening flow paths, using vegetative swales, maintaining natural flow paths, maximizing stream setbacks, and maximizing sheet flow.

4. Implementing LID integrated management practices (IMPs) that address runoff at its source by using design techniques that infiltrate, filter, store, evaporate, and detain runoff close to its source. Instead of conveying and treating stormwater in facilities located at the bottom of drainage areas, LID relies on practices such as open drainage swales, bioretention cells (similar to porous landscape detention), rain gardens, rain barrels, rooftop storage, depression storage,

soil amendments, infiltration swales and other similar features. A typical LID site will have multiple dispersed IMPs, rather than a single BMP at the low corner of a development.

5. Implementing pollution prevention practices that focus on maintenance practices and proper use, handling and storage of materials such as pesticides, fertilizers, household hazardous waste, etc.

Many of the components of the LID approach have been previously discussed in this chapter. The difference with LID is the overall site design process that incorporates all of the steps described above, resulting in a multi-faceted site design approach.

Because many LID features are natural in appearance and may rely on natural site features (e.g., preservation of soils with high infiltration capacities), it is imperative that the soil structure in these areas not be modified or compacted during construction, thereby reducing the natural infiltration capacity of the soil. This will require careful restriction on the routing of construction equipment, verification that infiltration capacities have been maintained, and possibly addition of soil amendments.

Another critical requirement for a successful LID site is assuring that regular and proper maintenance is conducted. If the dispersed LID components are not regularly maintained by a qualified and knowledgeable entity, the LID site will likely not function as intended. Similarly, when designing a LID site, it is important to ensure that the landscape practices (such as rain gardens) are attractive and perceived by the property owner as adding value to the property. If these LID practices are viewed as assets, the primary motivation for their long-term maintenance is that of property owners protecting their vested economic interests.

As of 2007, Springfield has not had significant experience with overall LID site designs, even though many of the LID components have been implemented at developments. Additional design guidance may be incorporated into this Manual in the future regarding LID. In the interim, the Low Impact Development Center website (www.lowimpactdevelopment.org/) should be referenced for more detailed design guidance, design drawings and specifications. For example, specifications for engineered soils can be downloaded from the LID website for bioretention cells and swales. LID site designs must be approved by the Department of Public Works and should be discussed early in the site planning process.

7.0 REFERENCES

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